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Development of an Ion Store/Time-of-Flight Mass Spectrometer for the Analysis of VOCs in Air

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The storehouse of analytical methods and equipment available for real-time air analysis has been on the rise since the 1990 enactment of the Clean Air Act Amendments. Of the non-spectroscopic techniques, mass-spectrometry has provided the best overall sensitivity, specificity and universal analysis capability. As with many non-spectroscopic detectors, mass analyzers are best suited for point source analysis of relatively large, non-reactive compounds in a complex matrix. For air monitoring, mass spectrometry is most commonly used in combination with gas chromatography (GC) for added selectivity. With this arrangement preconcentration on a solid phase adsorbent (e.g., Tenax) is often needed to achieve low- and sub-ppb (v/v) detection. This becomes an important consideration in real-time monitoring applications where preconcentration is not practical.

Recently, the ion trap mass spectrometer has been successfully used for air analysis because its ion storage capability provides a means for rapid preconcentration. Low ppb detection of VOCs in air has been demonstrated using direct capillary introduction and sub ppb detection has been achieved with membrane introduction. At the same time, time-of-flight mass spectrometry (TOF-MS) has emerged for fast GC analysis, providing submillisecond scan times and high analyzer throughput efficiencies. By combining the storage capability of the ion trap with the speed and efficiency of TOF-MS, a unique combination results that becomes well suited for real-time air monitoring.

Hardware and electronics used for the ion store/time-of-flight mass spectrometer (IS/TOF-MS), which uses only an 18" flight tube, were designed specifically for real-time air monitoring. To achieve high sensitivity, air is introduced directly into the ion trap through a small orifice. As a result, a high local pressure is sustained in the trap cavity that enhances ionization via charge exchange with N_2^+ and O_2^+ formed by electron impact (EI). The ion cloud is extracted for TOF-MS analysis by pulsing both endcaps at the proper rf phase of the ring electrode which, is simultaneously clamped to ground. This produces an acceptable spatial and energy distribution that can be focused in the TOF-MS.

The work presented here involves characterizing this new instrument approach for analysis of VOCs in air, especially in terms of the ionization process. At this time, detection limits are generally in the low to sub ppb (v/v) range when ion storage times are between 200 and 500 ms. Resolution exceeds 1200 m/Dm at FWHM. Mass accuracy is routinely 0.05% and scan-to-scan variations are less than 10 %.

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